

Impact of electromagnetic interferences on geodetic GNSS receivers: A comparative analysis among GPS, GLONASS, Galileo and BeiDou

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To investigate:

- **the impact of RFI on geodetic GNSS receivers**
- **the susceptibility of different GNSS signals to RFI**
- **the effectiveness of anti-jamming receiver technologies**

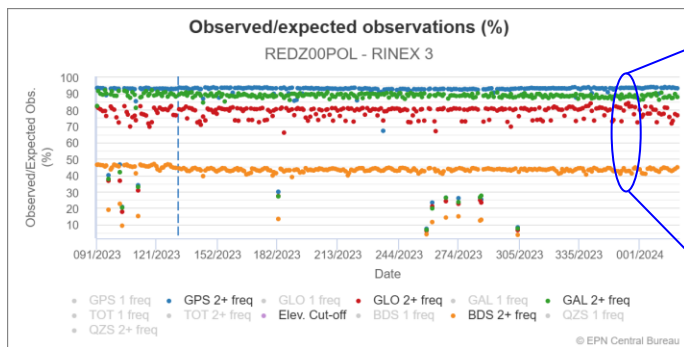
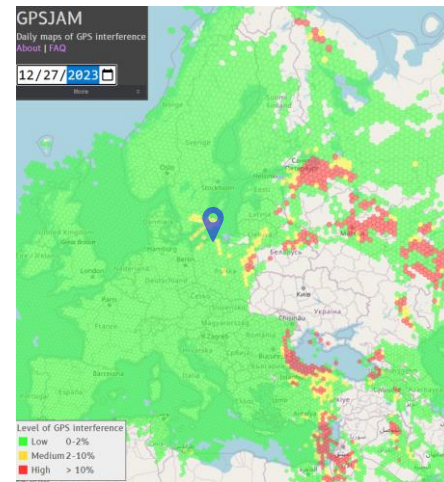
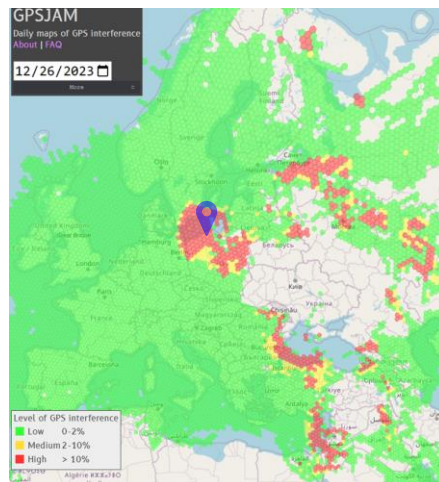
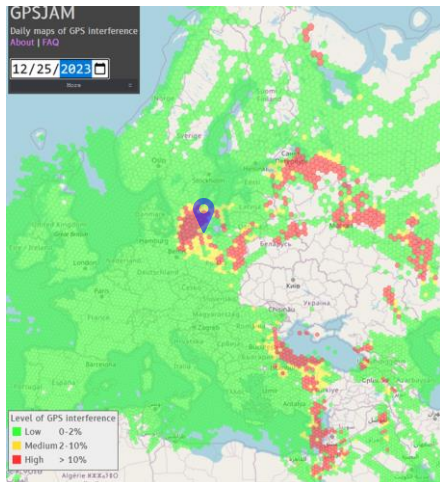
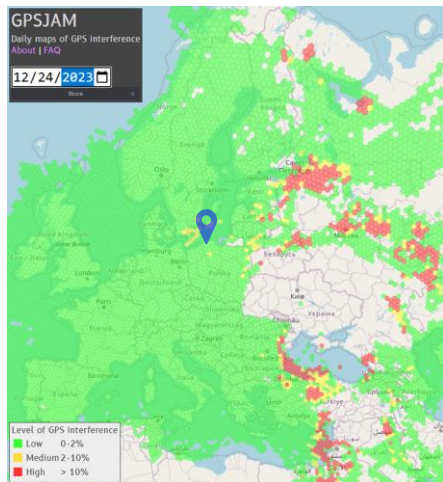
Receivers

- EPN CORS
- IGS CORS
- UniWA CORS
- RTK receivers

Jammers

- EW (Electronic Warfare)
- Own jammer

1. EPN Station REDZ Poland - EW

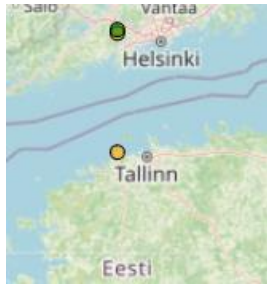


SNR values checked, no signs of RFI

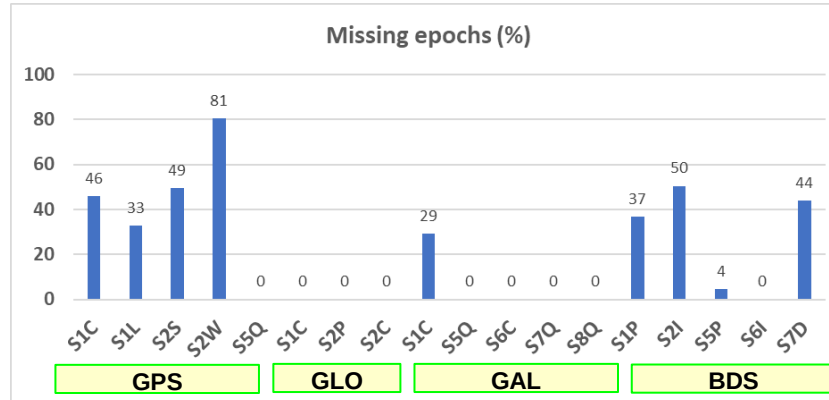
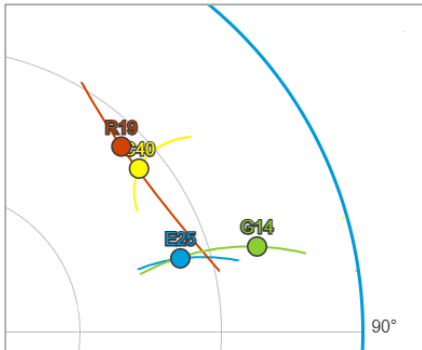
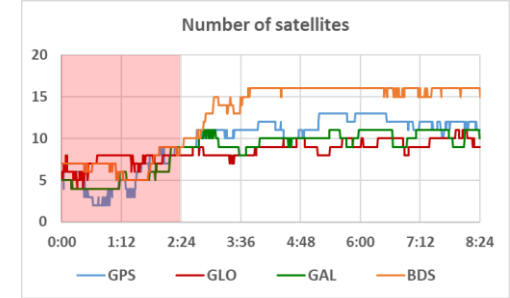
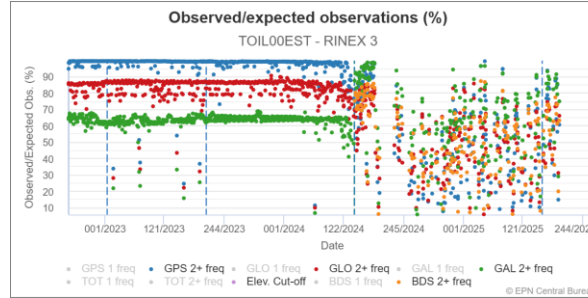
Indications of gpsjam.org usually not verified at ground stations

Data Analysis

2. EPN Station TOIL Estonia - EW



Rec. Leica GR50
Ant. LEIAR25.R4
Jammer EW
Date 31/5/2025
Status Decommissioned



Most affected:

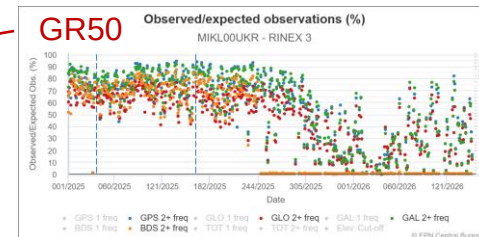
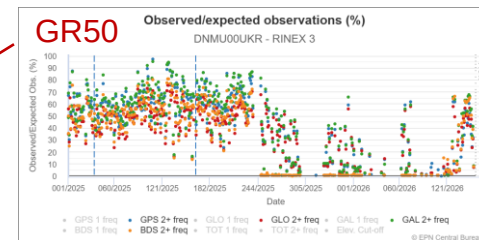
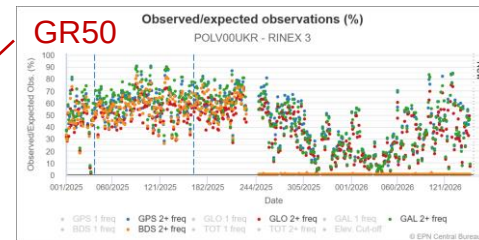
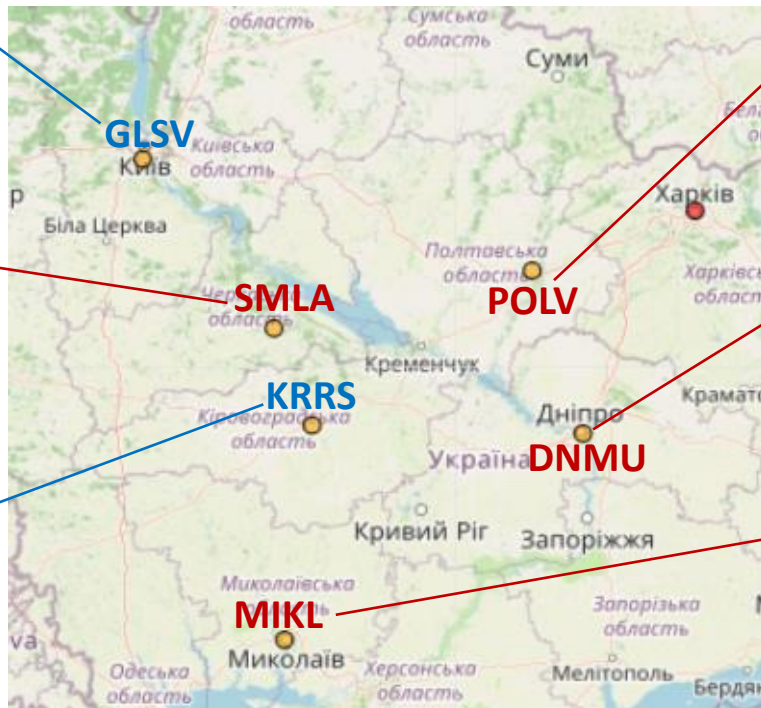
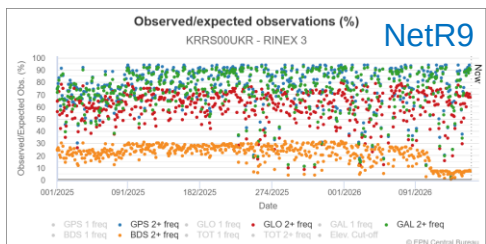
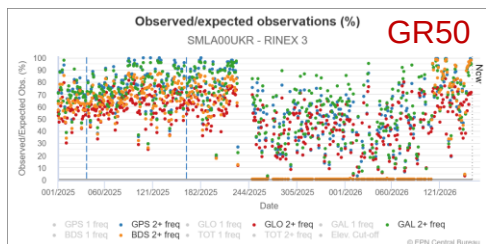
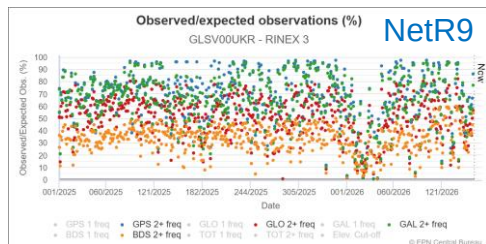
- L1, L2

Less affected:

- G1, G2, E5, E6, L5, B3

Data Analysis

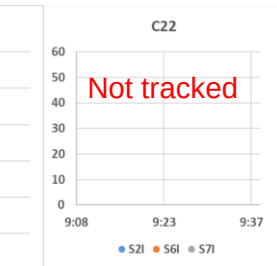
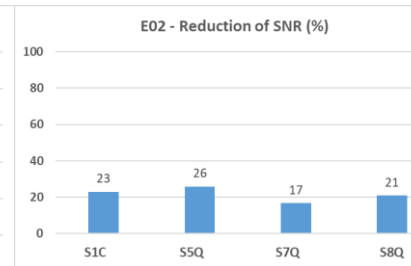
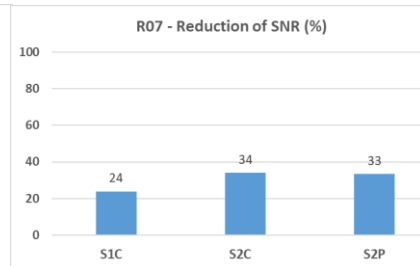
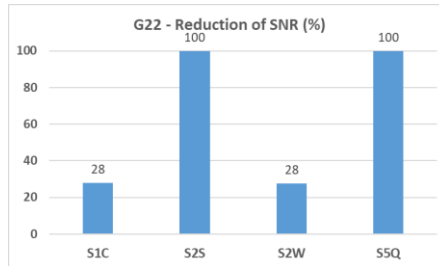
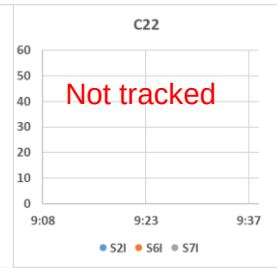
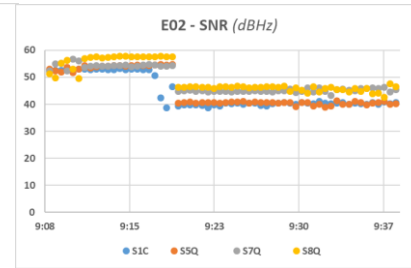
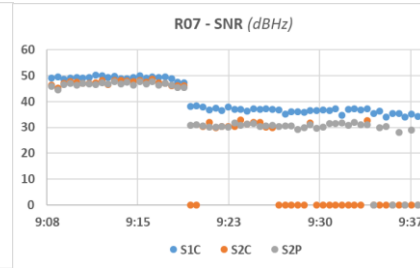
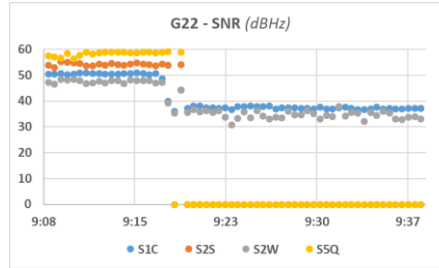
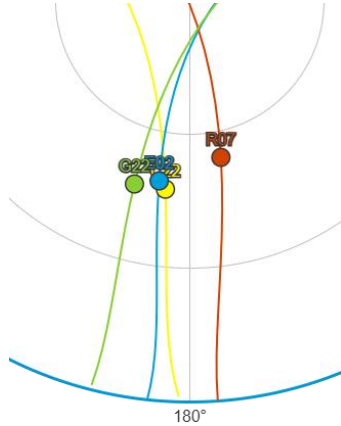
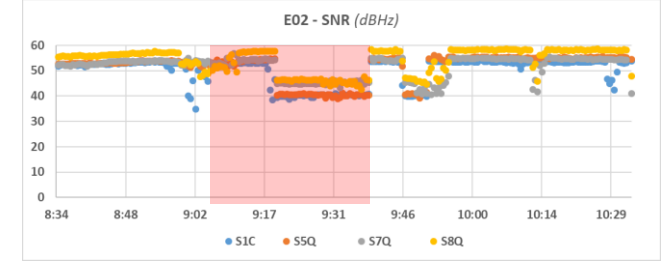
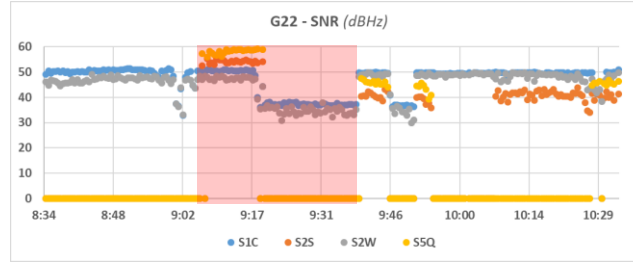
3. EPN Stations Ukraine - EW



Data Analysis

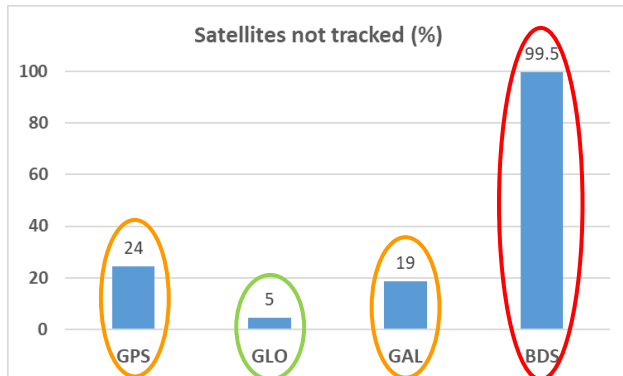
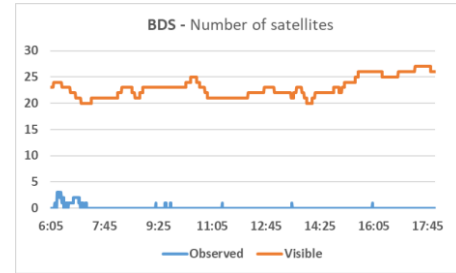
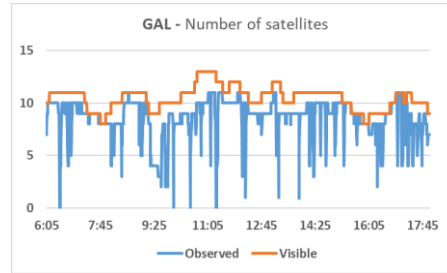
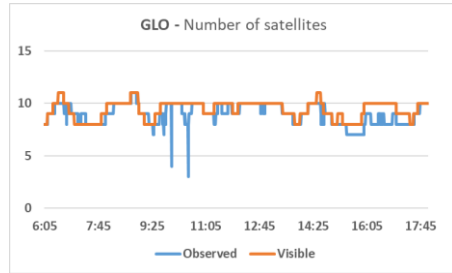
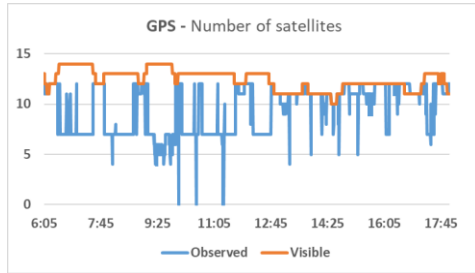
3. EPN Station DNMU Ukraine - EW

Rec. Leica GR50
Ant. LEIAR10
Jammer EW
Date 9/12/2025



Data Analysis

3. EPN Station DNMU Ukraine - EW



Fully jammed: BDS, L2C, L5

Less affected: GLO, GAL

Hard to explain:

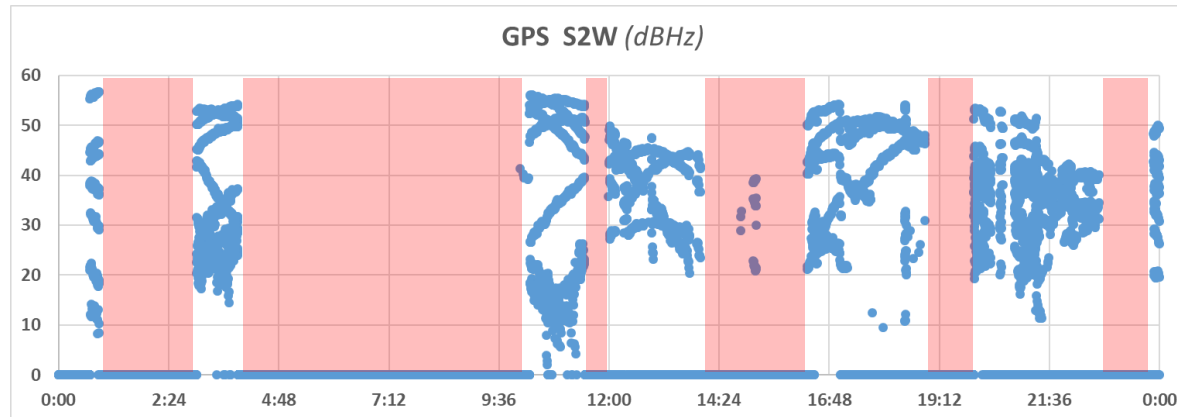
- Only BeiDou is fully jammed
- L5 fully jammed, while E5a tracked
- L2W tracked, while L2C not

Data Analysis

4. IGS Station BSHM Haifa - EW

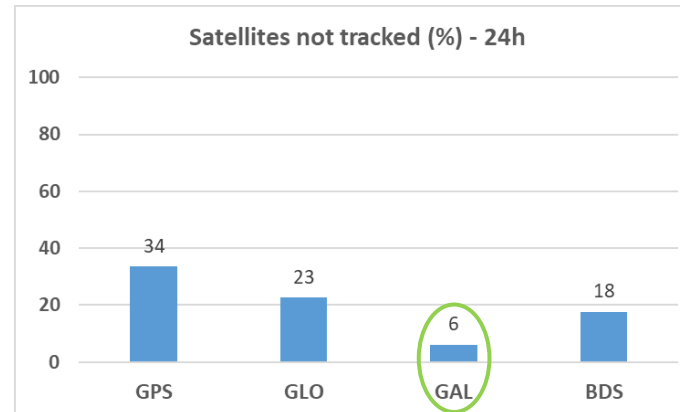
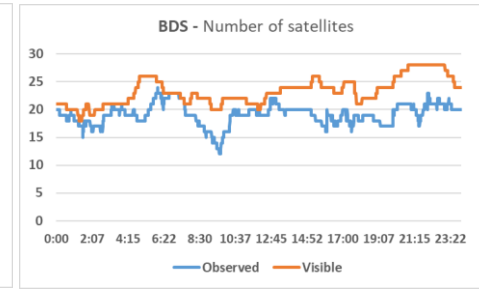
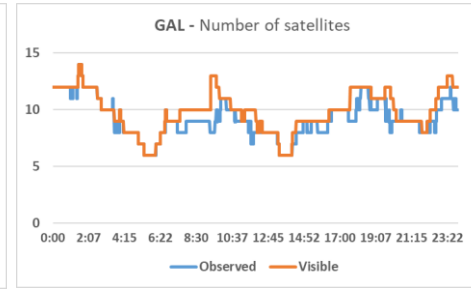
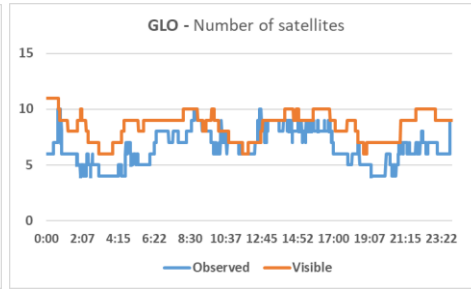
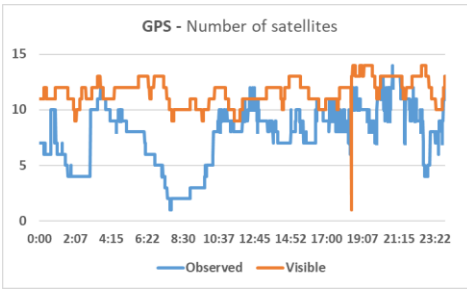


Rec. Septentrio PolarX5
Ant. Trimble Choke Ring SCIS
Jammer EW
Date 17/6/2025



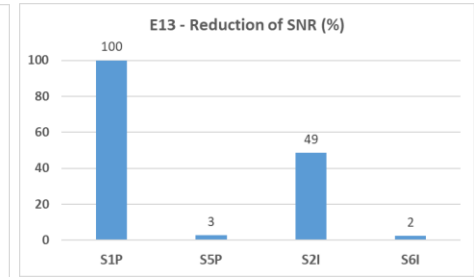
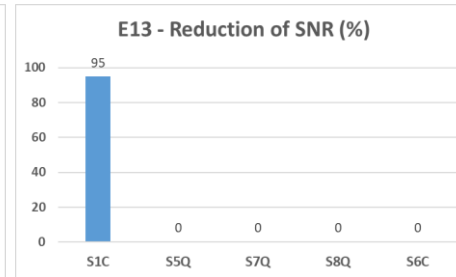
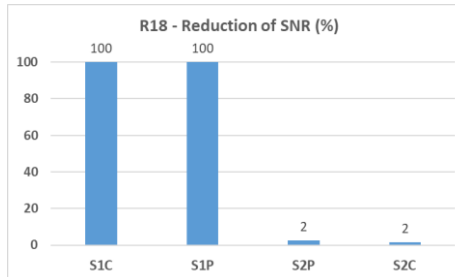
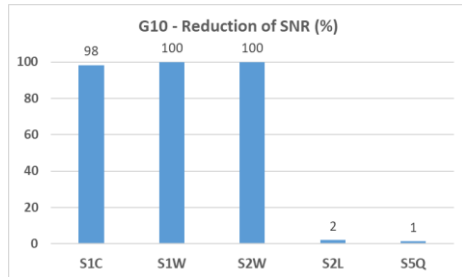
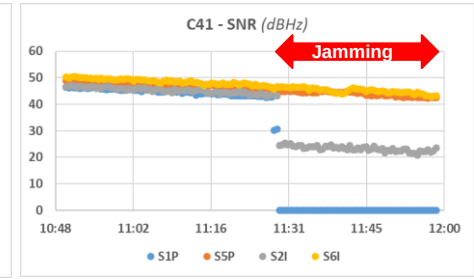
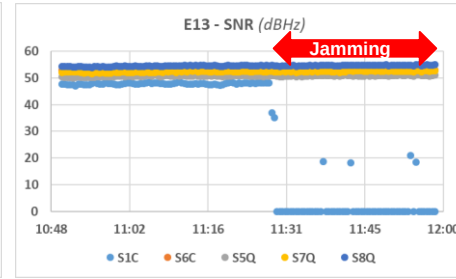
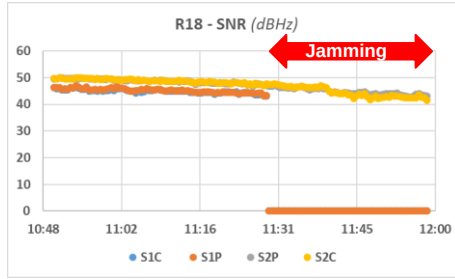
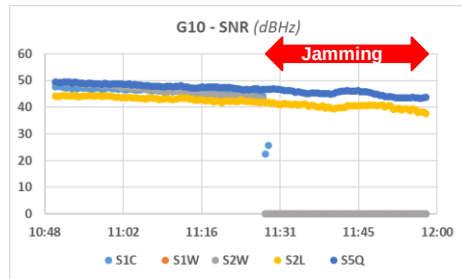
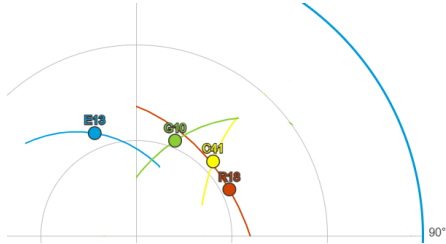
Data Analysis

4. IGS Station BSHM Haifa - EW



Data Analysis

4. IGS Station BSHM Haifa - EW

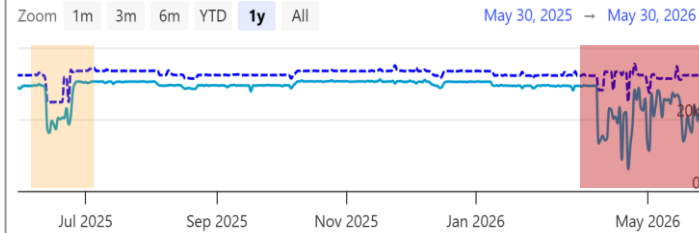


Data Analysis

4. IGS Station BSHM Haifa - EW

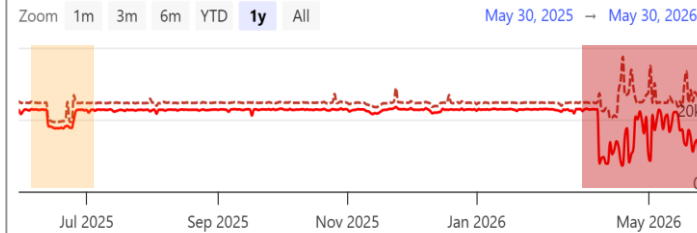
GPS

RINEX Observations



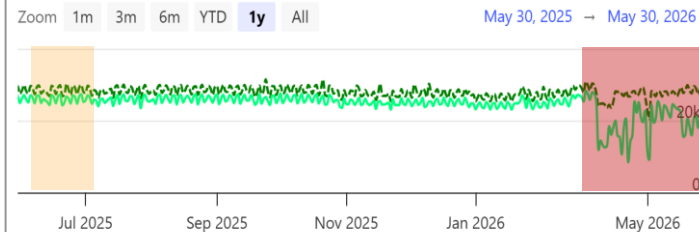
GLO

RINEX Observations



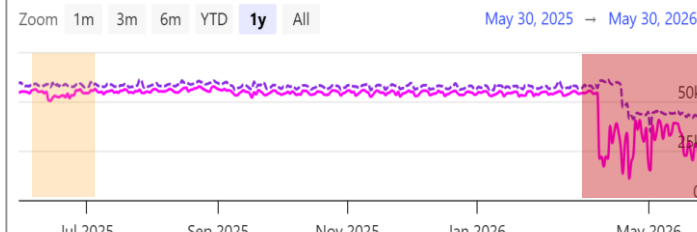
GAL

RINEX Observations



BDS

RINEX Observations



June 2025:

- L1 Jammer
- GPS mostly affected
- GAL less affected

Spring 2026:

- All GNSS affected

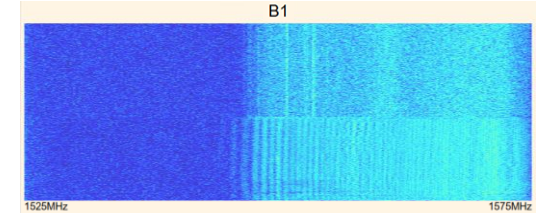
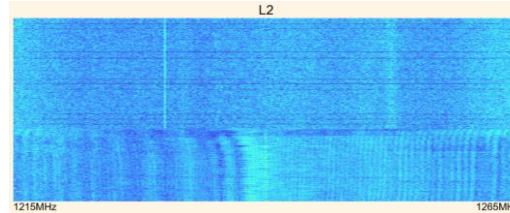
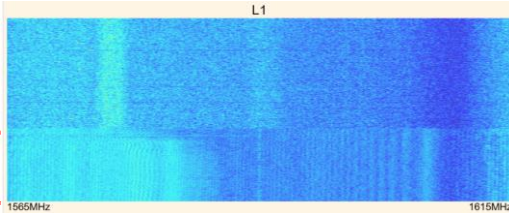
Data Analysis

5. Own jammer

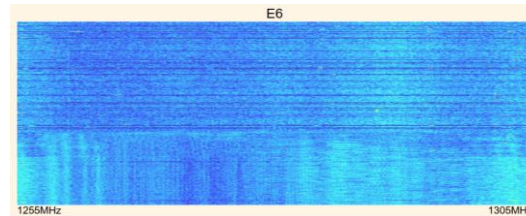
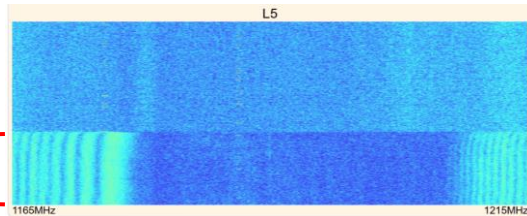


Power 0.8W / channel
Range ~ 5m
Freq. L1/G1/B1, L2/G2/B2, L5, E5b, E6

Jammer
on



Jammer
on

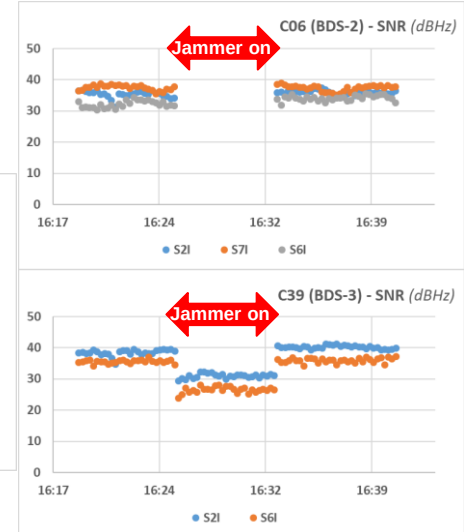
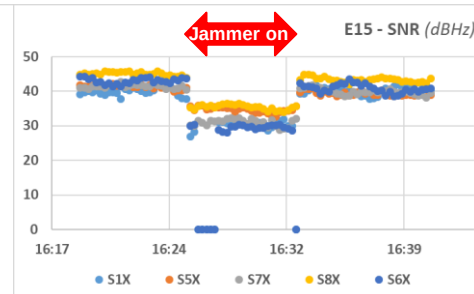
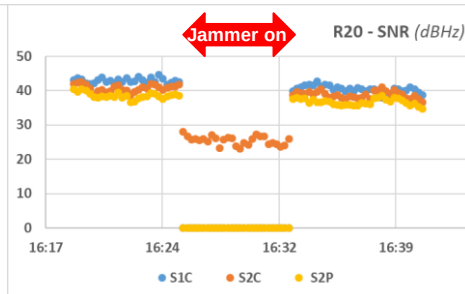
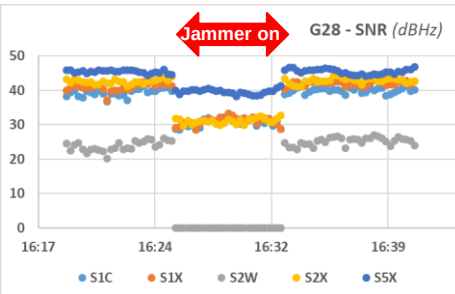


Data Analysis

5a. UniWA CORS - Own jammer

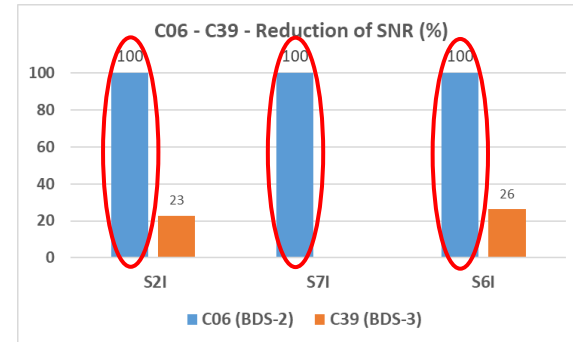
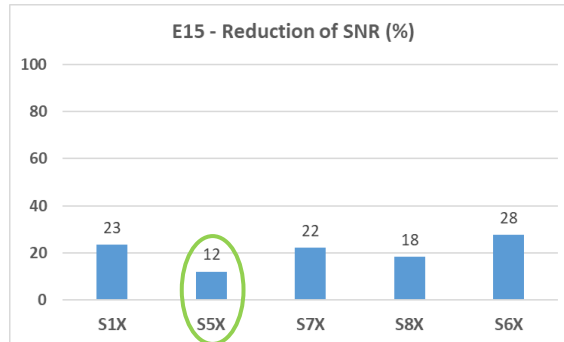
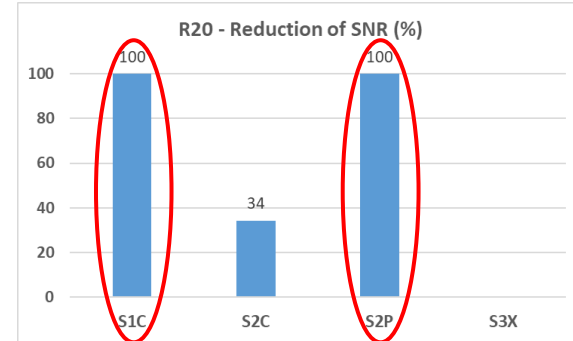
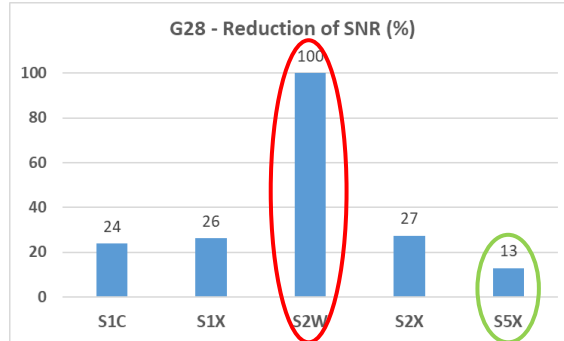
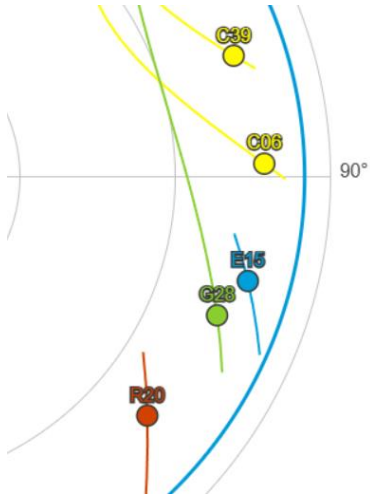


Receiver Trimble R750
Antenna Trimble Zephyr 3 Base
Jammer dist. 25m



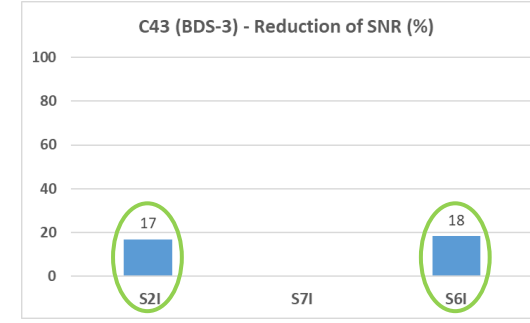
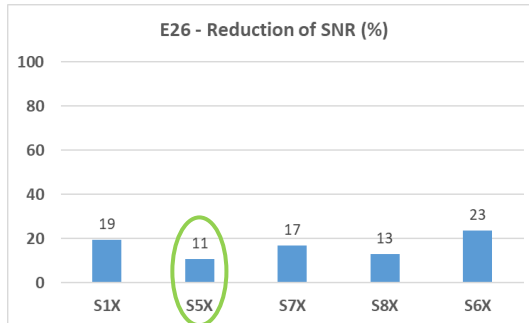
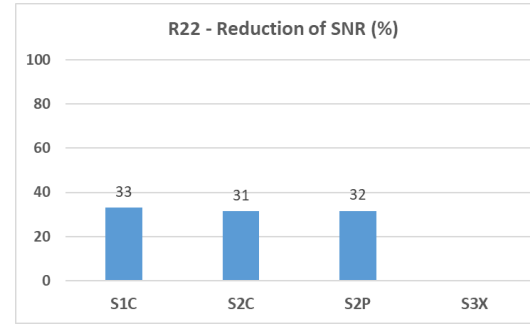
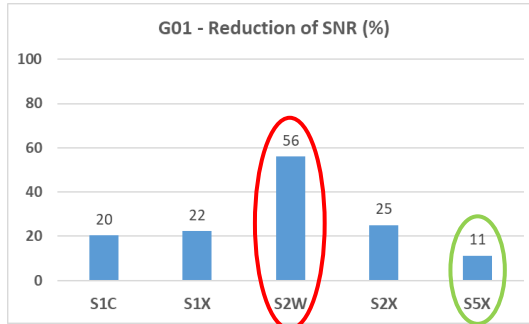
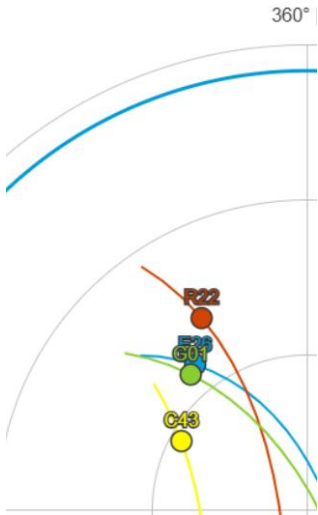
Data Analysis

5a. UniWA CORS - Own jammer - Low elevations



Data Analysis

5a. UniWA CORS - Own jammer - High elevations



Ranking
(worse to best):

- BDS-2
- GPS (L2W)
- GLO
- GPS
- GAL, GP(L5), BDS-3

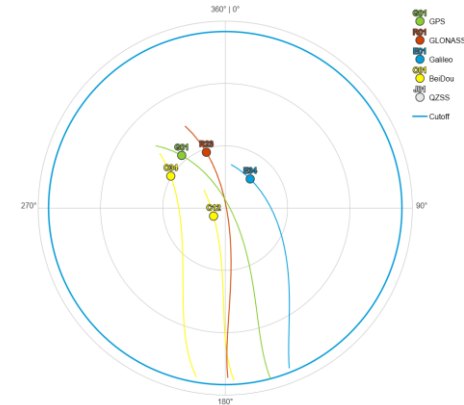
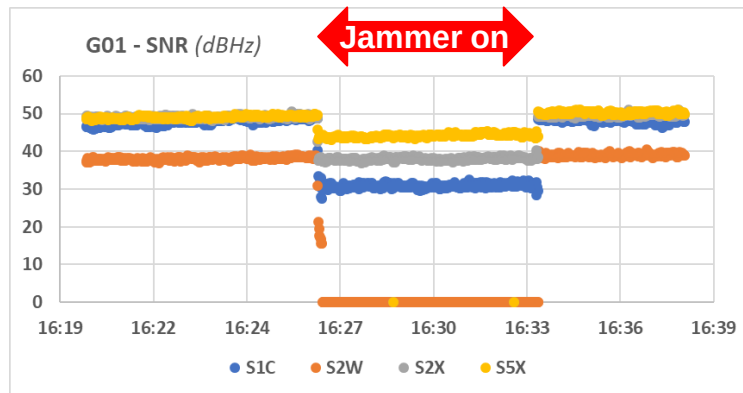
5b. RTK receivers - Own jammer - Receiver comparison



Receivers - Antennas:

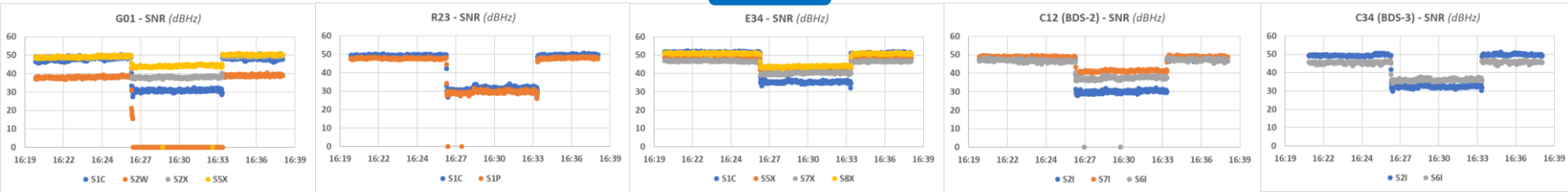
- JAVAD Triumph-1
- Spectra SP90m & TRM Zephyr 3 Base
- HiTarget iRTK5

Jammer dist. 9m

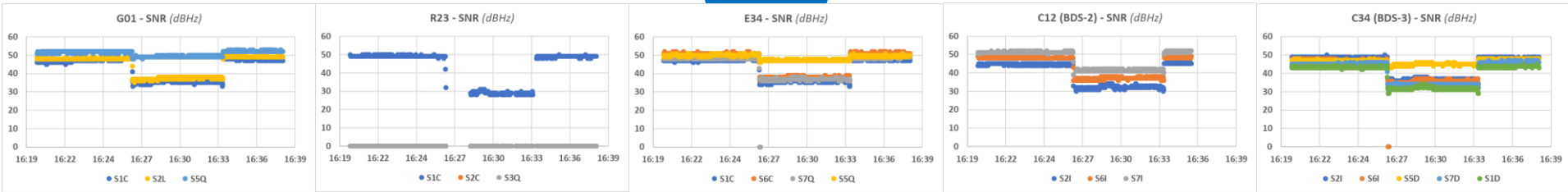


5b. RTK receivers - Own jammer - Receiver comparison

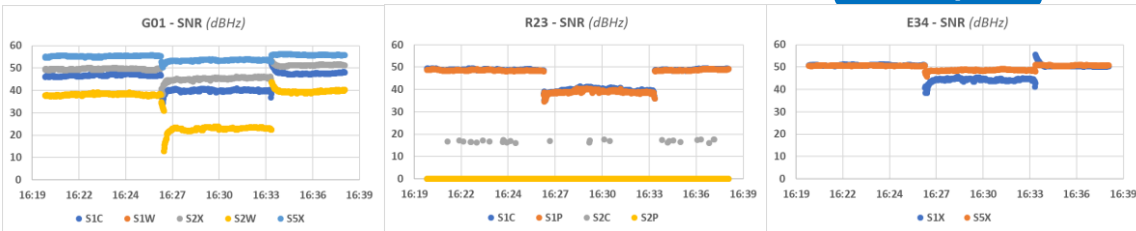
iRTK5



SP90m

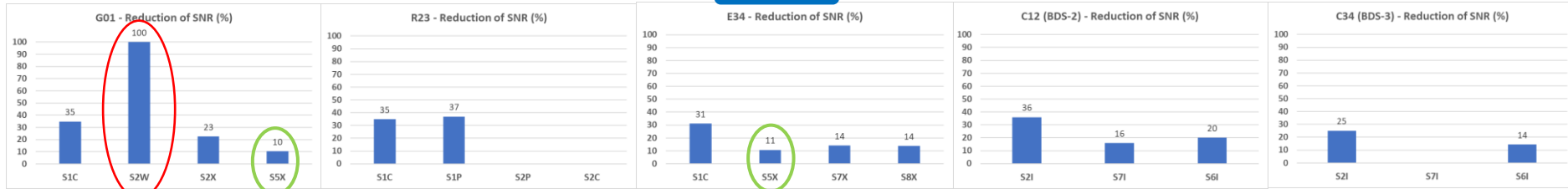


Triumph1

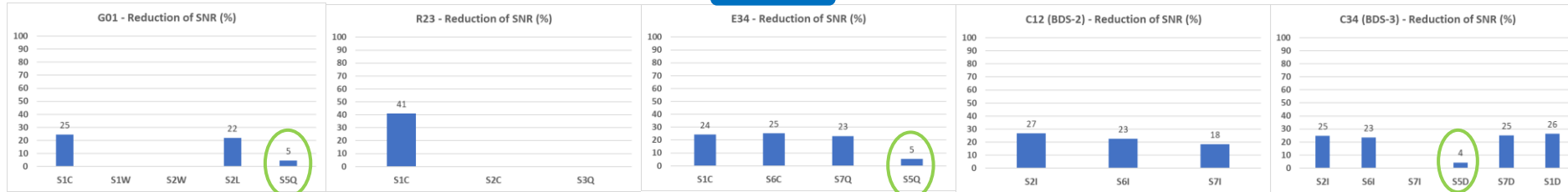


5b. RTK receivers - Own jammer - Receiver comparison

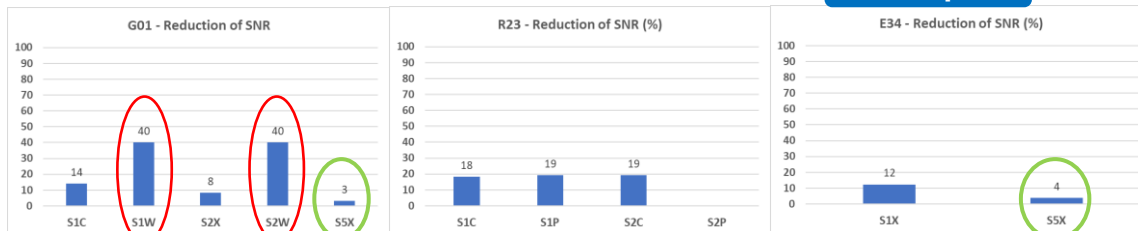
iRTK5



SP90m



Triumph1



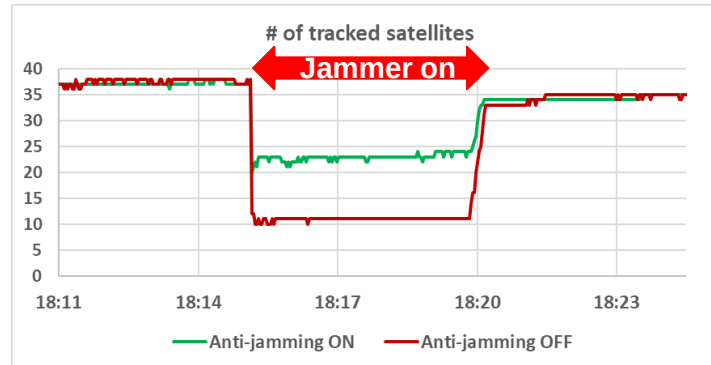
- Best: L5, E5, B2a
- Worst: L2W, L1W
- Triumph1 performs better

Data Analysis

5c. RTK receivers - Own jammer - Anti-jamming



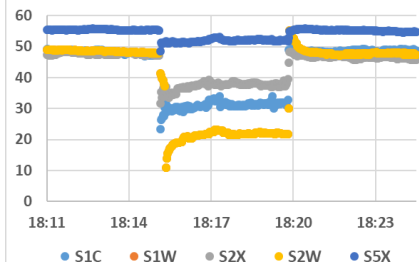
Receivers: 2 x JAVAD Triumph-1
Jammer dist. 9m



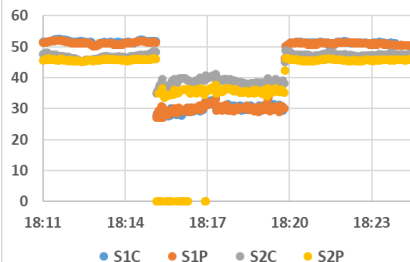
5c. RTK receivers - Own jammer - Anti-jamming

Anti-Jamming OFF

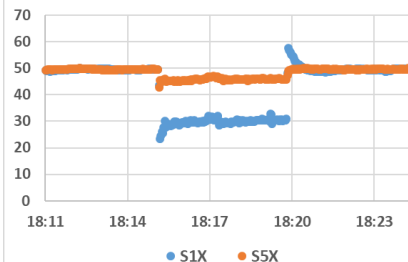
G09 - SNR (dBHz) anti-jamming OFF



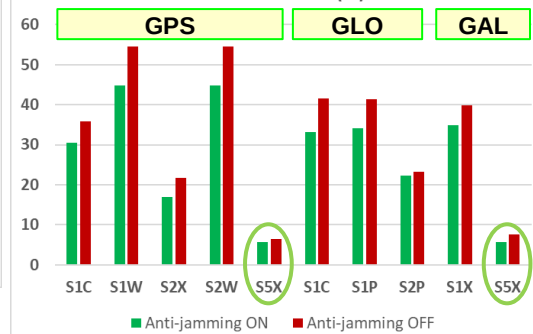
R11 - SNR (dBHz) anti-jamming OFF



E04 - SNR (dBHz) anti-jamming OFF

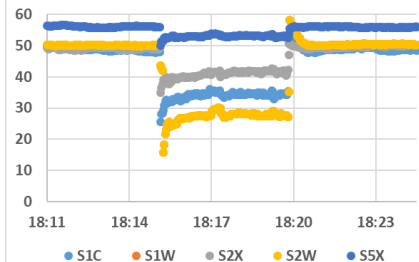


SNR Reduction (%)

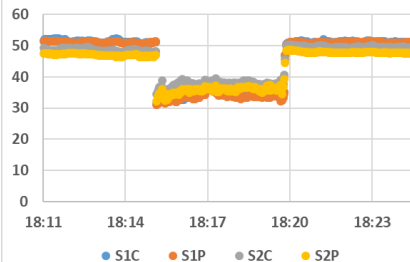


Anti-Jamming ON

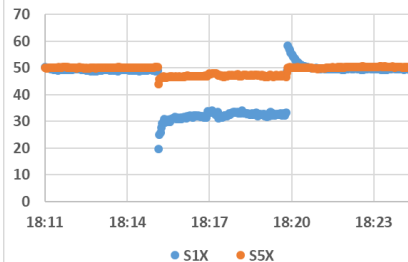
G09 - SNR (dBHz) anti-jamming ON



R11 - SNR (dBHz) anti-jamming ON



E04 - SNR (dBHz) anti-jamming ON



Anti jamming:

- More sats tracked
 - Improved SNR
- Best: L5, E5a

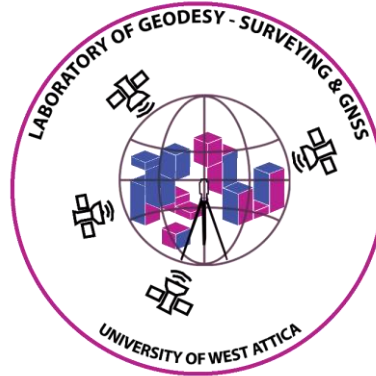
Conclusions

- **Aviation RFI info not always apply to ground receivers**
- **Impact of EW RFI varies strongly among GNSS / Signals**
- **Under equal jamming on all GNSS signals:**
 - ✓ Most problematic signals: Encrypted L1, L2
 - ✓ GNSS ranking (overall performance): GAL, BDS-3, GPS, BDS-2, GLO
 - ✓ Less affects signals: E5-L5-B2a
- **Anti-jamming receiver technologies can be very efficient**

Acknowledgements

- **EPN**
- **IGS**
- **Jaanus Metsar for information about RFI in ESTONIA**

Thank you for your attention!



GNSS frequencies

